Survival of THE PINK BOLLWORM Under Various Cultural and Climatic Conditions

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Survival of THE PINK BOLLWORM Under Various Cultural and Climatic Conditions

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The pink bollworm (*Pectinophora gossypiella* (Saund.)) was found in several eastern Texas counties in 1917. By eradicating the infestations there and a few other isolated ones, the insect was pushed back to the area along the Mexican border in western Texas, where it has persisted since 1918 (Curl and White *5*).[2] It was not found in the lower Rio Grande Valley until 1936. Gradual spread from these border areas has continued intermittently. The insect now occurs throughout the cotton-producing areas of Texas, New Mexico, and Oklahoma and in sections of Arizona, Arkansas, and Louisiana.

The pink bollworm spends the winter in the larval stage. The overwintering worms are frequently referred to as long-cycle, resting, or diapause larvae, whereas those that pupate immediately after they complete feeding are known as the short-cycle type. The percentage of larvae entering the resting stage increases during the last part of each crop season because of cooler temperature and other factors (Chapman and Hughs *3*). Most overwintering larvae are found in the seed of bolls in which they developed. However, some that have cut their way out of green bolls enter the resting stage in cocoons they spin on the soil, known as free cocoons; others may remain in fallen blooms and spin cocoons. Those surviving the winter to infest the next crop are usually in the crop residues that remain in the fields after harvest, and they are especially susceptible to control by cultural practices.

Experiments to determine the survival of overwintering larvae under various soil, climatic, and cultural conditions have been in progress in this country since 1927. Until recent years most of the work was conducted in the Presidio and El Paso Valleys, which are in the arid section of southwestern Texas, and in the lower Rio Grande Valley, which is subtropical. Experiments in newly infested areas were begun in the fall of 1952 at seven localities in Texas and one in Oklahoma. Since that time

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[1] Others who assisted in this study were Ivan Shiller, W. L. Lowry, J. C. Clark, C. A. Richmond, C. R. Parencia, J. W. Davis, and C. B. Cowan of the Entomology Research Division; Q. A. Hare, H. S. Cavitt, W. F. Sennett, D. H. Russell, F. M. Wilson, and H. B. Prickett of the Plant Pest Control Division; and Dow D. Porter of the Crops Research Division. Through cooperation with the Arkansas and the Oklahoma Agricultural Experiment Stations, valuable help was received from Charles A. Lincoln and T. F. Leigh of the former station and E. S. Oswalt and D. E. Bryan of the latter.

[2] Italic numbers in parentheses refer to Literature Cited, p. 20.

experiments were also conducted in bioclimatic cabinets at Brownsville, Tex., where weather conditions at widely separated points representative of uninfested parts of the Cotton Belt were simulated.

Results of some of the early experiments have been reported by Chapman and Cavitt (*1* and *2*), Chapman and Hughs (*3*), Fenton et al. (*6*), Fenton and Owen (*7*), Fife et al. (*8*), Isler and Fenton (*10*), and Noble (*11*). In this report some of the more important findings in previous publications are reviewed, more recent unpublished data are reported, and pertinent observations during the long period in which this study was in progress are discussed.

Methods

Infested open bolls and larvae in free cocoons were exposed in wooden frames that afforded little or no protection during the winter, as the covers to form a cage were not installed until spring. The 3-foot square frame was constructed from a 1- by 8-inch board, and the bottom of the frame was embedded in the soil to a depth of 4 to 5 inches. In the early experiments the top of the frame was covered with black cloth equipped with screen-wire traps for recovering the moths. A screen-wire pyramid-type cover with a trap at the apex was later developed and proved to be much more efficient in moth recovery (Shiller *12*). The temperature and humidity under the pyramid cover also more closely approximated natural conditions. These covers were used in all experiments after the winter of 1941.

Open bolls harvested in heavily infested fields were thoroughly mixed, and samples taken at random were examined for pink bollworm as a means of estimating the population per pound. Equal amounts of bolls were placed in each cage, ranging from 3 to 4 pounds per cage for the various experiments, depending on the degree of infestation.

Larvae in free cocoons were obtained by placing several hundred heavily infested green bolls in a wooden tray, 3 by 3 by ⅔ feet, with a ¼-inch mesh hardware cloth bottom. The tray was placed directly over the bottom of the installed hibernation cage. As larvae emerged from the green bolls, they dropped to the soil and spun cocoons inside the cage. From 4 to 6 weeks after the larvae ceased to leave the bolls, the soil in several cages was examined to determine the number of larvae per cage. Traps in the cage covers were examined almost daily, starting with spring emergence, and the number of moths that emerged in each cage was recorded. The percent survival was calculated from the number of moths recovered.

Climates Represented

Climatic conditions at localities in which experiments were conducted in Texas range from subtropical and humid at Brownsville to cold and arid in the western part of the State. In some experiments cold winters with heavy rainfall were simulated in bioclimatic cabinets. Climatological data for the various localities during the experiments are summarized in table 1.

TABLE 1.—*Winter temperature and rainfall for various localities during the pink bollworm experiments*

Winters	Winter temperature			Rainfall	
	Lowest	Average minimum [1]	Average maximum [1]	Fall and winter [2]	Spring [3]
	°F.	*°F.*	*°F.*	*Inches*	*Inches*
ATHENS, GA.					
1955–56	17	33. 9	54. 6	11. 94	15. 98
BROWNSVILLE, TEX.					
1952–53	38	53. 5	73. 5	9. 87	1. 58
1953–54	32	53. 9	73. 8	4. 76	4. 36
1954–55	35	54. 6	73. 4	18. 08	1. 26
1955–56	34	54. 0	74. 4	12. 16	11. 48
1956–57	33	48. 3	70. 3	5. 44	17. 60
CHICKASHA, OKLA.					
1952–53	9	30. 6	55. 9	5. 64	9. 92
1953–54	3	29. 9	59. 6	2. 77	11. 70
1954–55	12	30. 0	54. 5	4. 98	14. 57
1955–56	5	26. 9	53. 3	1. 41	9. 25
1956–57	12	31. 4	53. 0	4. 55	20. 55
EL PASO, TEX.					
1945–46	6	24. 9	60. 0	0. 61	1. 34
1946–47	4	27. 0	58. 8	1. 92	1. 78
1947–48	−6	24. 2	58. 3	1. 00	. 75
1948–49	−2	28. 1	56. 4	3. 39	1. 46
1949–50	10	30. 1	61. 7	1. 88	0
1950–51	6	27. 6	63. 2	1. 06	. 53
1951–52	16	32. 1	62. 8	1. 07	3. 31
GREENVILLE, TEX.					
1952–53	19	36. 0	56. 6	14. 98	11. 42
1953–54	12	35. 6	58. 8	13. 32	11. 68
1954–55	14	35. 2	56. 3	8. 97	10. 41
1955–56	12	33. 4	55. 6	7. 68	8. 34
1956–57	13	38. 3	57. 6	13. 42	44. 12
GREENWOOD, MISS.					
1954–55	21	36. 2	56. 0	20. 27	21. 75
1955–56	16	37. 0	56. 7	21. 46	18. 87

See footnotes on p. 5.

TABLE 1.—*Winter temperature and rainfall for various localities during the pink bollworm experiments*—Continued

LUBBOCK, TEX.

Winters	Winter temperature			Rainfall	
	Lowest	Average minimum [1]	Average maximum [1]	Fall and winter [2]	Spring [3]
	°*F.*	°*F.*	°*F.*	*Inches*	*Inches*
1952–53	9	29. 5	61. 9	1. 40	2. 89
1953–54	3	27. 9	62. 1	. 12	7. 75
1954–55	5	28. 2	55. 2	1. 63	4. 01
1955–56	5	28. 1	58. 1	. 72	4. 94
1956–57	9	33. 1	59. 8	1. 20	14. 96
MALDEN, MO.					
1955–56	10	28. 3	46. 9	12. 18	13. 04
1956–57	8	32. 7	49. 4	16. 42	27. 35
MEMPHIS, TENN.					
1955–56	15	34. 3	51. 7	18. 10	16. 40
MOUNT PLEASANT, TEX.					
1953–54	13	35. 5	61. 6	12. 42	11. 10
1954–55	15	33. 2	58. 0	9. 27	10. 93
1955–56	11	32. 2	57. 1	11. 70	7. 84
1956–57	12	38. 6	60. 0	11. 10	27. 69
PORT LAVACA, TEX.					
1952–53	30	------------	------------	8. 53	17. 34
1953–54	27	48. 7	68. 8	8. 50	7. 48
1954–55	30	48. 6	68. 0	7. 66	10. 22
1955–56	29	47. 4	68. 7	5. 94	6. 80
1956–57	30	51. 6	70. 3	7. 57	27. 92
PRESIDIO, TEX.					
1935–36	17	33. 7	69. 1	0. 71	2. 69
1936–37	19	31. 8	69. 0	1. 04	. 98
1937–38	19	37. 4	67. 8	2. 99	2. 39
1938–39	18	29. 9	68. 7	1. 65	2. 74
1939–40	18	33. 7	68. 0	3. 20	5. 38

See footnotes on p. 5.

TABLE 1.—*Winter temperature and rainfall for various localities during the pink bollworm experiments*—Continued

VERNON, TEX.

Winters	Winter temperature			Rainfall	
	Lowest	Average minimum [1]	Average maximum [1]	Fall and winter [2]	Spring [3]
	°F.	*°F.*	*°F.*	*Inches*	*Inches*
1952–53	13	34. 3	61. 7	3. 37	7. 66
1953–54	11	32. 8	63. 1	1. 11	15. 98
1954–55	2	31. 4	57. 3	3. 19	17. 41
1955–56	15	31. 4	57. 3	1. 32	4. 23
1956–57	15	34. 8	59. 2	4. 25	27. 06
WACO, TEX.					
1952–53	21	40. 1	61. 9	13. 28	15. 24
1953–54	19	40. 0	62. 4	5. 23	8. 02
1954–55	21	39. 8	61. 5	7. 26	14. 12
1955–56	20	38. 7	61. 0	5. 56	5. 31
1956–57	20	42. 3	62. 1	8. 22	27. 58

[1] Average of daily records for December through January.
[2] September through January at Brownsville, October through January at Port Lavaca, and November through February at all other localities.
[3] February through June at Brownsville and Port Lavaca and March through June at all other localities.

Survival in Bolls and Free Cocoons

Experiments were conducted at Brownsville to determine the winter survival of larvae in free cocoons and blooms. Results indicate that all such larvae pupate and emerge as moths during the fall or winter; consequently, none are left to infest the next crop in the subtropical lower Rio Grande Valley.

Experiments were conducted at Presidio, El Paso, Waco, and Port Lavaca, Tex., to compare survival of larvae in open cotton bolls and free cocoons under identical treatments. The data in table 2 show that survival in free cocoons was much lower than that in bolls. In nonirrigated treatments survival in bolls was approximately 4 to 15 times greater than survival in cocoons at Presidio, about 8 times greater at El Paso, and 12 times greater at Waco. There was no winter carryover in cocoons during 1 of 2 years at Port Lavaca, where mild weather induced fall and winter pupation. Winter irrigation at Presidio was more effective in decreasing survival of larvae in free cocoons than in bolls; thus, carryover of the fall cocoon population would appear to be of very little economic importance in areas with heavy rainfall.

TABLE 2.—*Pink bollworm survival in open cotton bolls and free cocoons in experiments at four localities in Texas*

Locality	Winters	Winter treatment	Larvae in—		Survival in—	
			Bolls	Cocoons	Bolls	Cocoons
			Number	*Number*	*Percent*	*Percent*
Presidio [1]	1936–37	Buried 2–6 inches, 2 irrigations	14, 850	16, 068	4. 4	0. 1
		Buried 2–6 inches, 1 irrigation	14, 850	16, 068	7. 0	. 2
		Buried 2–6 inches	14, 850	16, 068	15. 5	1. 0
	1937–41	(2)	129, 949	131, 962	12. 8	3. 0
El Paso	1945–48	Buried 2–4 inches Dec. 15	8, 860	14, 016	11. 6	1. 5
		Buried 2–4 inches Mar. 15	8, 860	14, 016	13. 3	1. 4
		Not buried	8, 860	14, 016	16. 3	2. 0
Waco	1956	Not buried	12, 513	4, 848	9. 8	. 8
Port Lavaca	1954–55	do	12, 108	6, 789	8. 7	. 02

[1] All experiments prior to 1942 were conducted in the black cloth-type cage, which reduced survival in both bolls and cocoons.
[2] Bolls and cocoons were exposed to the same nonirrigated treatments, which varied from year to year.

Survival in Clay and Sandy Soils at Presidio

Experiments at Presidio comparing pink bollworm survival in a heavy clay soil and a sandy soil were conducted during the winters of 1928–30 and 1938. Infested bolls were buried 2 to 6 inches in cages that were covered in the spring with black cloth covers. Table 3 shows that winter survival was two to three times greater in clay than in sandy soil.

TABLE 3.—*Pink bollworm survival in open cotton bolls buried in clay and sandy soil, Presidio, Tex.*

Winters	Depth buried	Date of irrigation	Larvae in each soil type	Survival in—	
				Clay soil	Sandy soil
	Inches		*Number*	*Percent*	*Percent*
1928–30	4	None	59, 146	3. 1	1. 4
1938	2–6	Mar. 15	14, 760	7. 9	2. 5

Cultural Treatments at Presidio

The following experiments at Presidio were conducted prior to the development of the cage with the screen pyramid cover.

Time and depth of burial and winter irrigation

Studies on the effects of time and depth of winter burial and winter irrigation on survival of larvae in bolls in clay soil were conducted during the winters of 1935–39. In these experiments infested bolls were placed on the soil surface in all cages on December 1 and were buried and irrigated in accordance with the dates shown in table 4. In each treatment

TABLE 4.—*Pink bollworm survival in open cotton bolls buried in clay soil subjected to various winter cultural treatments, Presidio, Tex., during winters of 1935–39*

Date buried	Date of irrigation [1]	Survival at burial depth (inches)[2] of—			Average survival
		2	4	6	
		Percent	*Percent*	*Percent*	*Percent*
Dec. 1	Dec. 15 and Jan. 15	4. 1	1. 2	0. 5	2. 0
	Dec. 15	8. 8	3. 7	. 5	4. 3
	None	26. 1	11. 5	5. 0	14. 2
Jan. 1	Jan. 15 and Feb. 15	10. 5	1. 9	. 7	4. 4
	Jan. 15	19. 1	4. 1	1. 7	8. 3
	None	26. 2	7. 6	5. 7	13. 2
Feb. 1	Feb. 15	14. 6	4. 1	1. 5	6. 7
	None	15. 5	13. 1	6. 5	11. 7
Mar. 1	None	10. 8	11. 1	5. 7	9. 2
Average		15. 1	6. 5	3. 1	

[1] Irrigation on Mar. 15 was included in all treatments.
[2] 5,150 pink bollworm larvae were embedded at each depth in each treatment.

there were three burial depths, with equal amounts of infested bolls at each depth. Approximately 7 inches of water were applied at each irrigation. An irrigation on March 15, given in all treatments, simulated the spring irrigation that is applied shortly before cotton is planted in this area.

Winter irrigation following winter burial of bolls greatly decreased pink bollworm survival, and two winter irrigations were more effective than one, as shown in table 4. The earlier in the winter bolls were buried and irrigated, the lower was survival; however, when not irrigated, there was no marked difference in survival for the various winter burial dates. As the depth of burial increased, survival decreased. The percent survival averaged 15.1 at 2, 6.5 at 4, and 3.1 at 6 inches.

Spring irrigation

The effect of spring irrigation on pink bollworm survival in the arid Presidio climate was determined in experiments summarized in table 5. Survival was higher with spring irrigation than without it. The lower survival in nonirrigated soil is attributed to lack of moisture to stimulate pupation.

TABLE 5.—*Pink bollworm survival in open cotton bolls buried in clay soil, with and without spring irrigation, Presidio, Tex.*

Winters	Date buried	Date of irrigation	Larvae buried	Survival
			Number	*Percent*
1928–34	Mar. 1–10	Mar. 15	15, 163	7. 1
		None	14, 892	2. 8
1937–40	Dec. 1	Mar. 15	7, 377	12. 3
		None	7, 377	6. 8

Cultural Treatments at El Paso

Experiments with pink bollworm larvae in bolls were conducted on medium-heavy clay soil in the El Paso Valley from 1944 into 1952. Infested bolls were placed in cages on the first of December and given treatments simulating various cultural practices as follows: (1) Buried on December 15, (2) exposed on soil surface until buried on March 15, (3) exposed on soil surface throughout the experiment, and (4) exposed aboveground, simulating standing stalks, until buried on March 15. The bolls in each burial treatment were placed at depths of 2 and 4 inches, with equal amounts at each depth. An irrigation was applied the first of April and two to three additional irrigations to stimulate pupation were applied as needed, based on a decrease in daily moth emergence.

Yearly survival from the various treatments is shown in table 6. Survival in the December burial was slightly lower than that in the March burial after exposure of bolls on the soil surface during the winter. In

this cold climate the survival was lowest in bolls exposed aboveground, simulating standing stalks, until buried on March 15—0.9 percent in this treatment as compared with 18.4 percent for bolls exposed on the soil surface until buried on the same date and 18.2 percent for bolls left on the soil surface. Survival in bolls that were not buried fluctuated from year to year above and below the survival in surface bolls that were buried on March 15. Undoubtedly this fluctuation was due to some influence during the pupation and moth-emergence period, such as lack of moisture to stimulate pupation and consequent desiccation of the larvae, or mortality due to high temperature. Exceptionally low survival occurred in all treatments during the winters of 1947–48 (see p. 18).

Table 6.—*Pink bollworm survival in open cotton bolls under various cultural treatments, El Paso Valley, Tex.*

Winter	Buried Dec. 15	Exposed on soil surface until buried Mar. 15	Not buried	Exposed aboveground until buried Mar. 15	Average
	Percent	*Percent*	*Percent*	*Percent*	*Percent*
1944	17. 6	19. 4	30. 5	4. 9	18. 1
1945	24. 7	25. 5	15. 5	. 2	16. 5
1946	10. 5	11. 2	19. 9	. 4	10. 5
1947	2. 4	3. 7	8. 9	. 6	3. 9
1948	2. 8	6. 5	6. 5	. 8	4. 2
1949	16. 6	28. 8	16. 2	. 2	15. 4
1950	25. 1	33. 3	25. 5	. 1	21. 0
1951	9. 4	18. 5	23. 0	. 3	12. 8
Average	13. 6	18. 4	18. 2	. 9	12. 8

Uniform Cultural Treatments at Eight Localities

Experiments including four uniform treatments of bolls at seven widely separated localities in Texas and one place in Oklahoma were begun in the fall of 1952 and continued into 1957. The four treatments of infested bolls were as follows: (1) Buried in the fall, (2) exposed on soil surface until buried in the spring, (3) exposed on soil surface throughout the experiment, and (4) exposed aboveground, simulating standing stalks, until buried in the spring. In all burial treatments the bolls were placed at a depth of 2 inches.

Because of wide variation in growing seasons at the different locations, the experiments were begun on different dates, as indicated in table 7 (see footnotes). Bolls in the fall burial treatments were buried at the time they were placed in the cages. Screen pyramid covers equipped with moth traps were placed on the cages on March 1 at Brownsville and Port Lavaca and on April 1 at all other locations.

Table 7.—*Pink bollworm survival in open cotton bolls under various cultural treatments in Texas and Oklahoma*

BROWNSVILLE, TEX.

Winter	Buried in fall [1]	Exposed on soil surface until buried in spring [2]	Not buried	Exposed above-ground until buried in spring [2]	Average
	Percent	*Percent*	*Percent*	*Percent*	*Percent*
1952	0	0. 04	0. 01	0. 15	0. 05
1953	1. 23	1. 97	4. 42	5. 07	3. 17
1954	. 02	. 06	. 22	1. 43	. 43
1955	. 05	. 07	. 56	. 69	. 34
1956	----------	. 70	1. 86	3. 35	--------

PORT LAVACA, TEX.

Winter	Buried in fall [1]	Exposed on soil surface until buried in spring [2]	Not buried	Exposed above-ground until buried in spring [2]	Average
1952	0. 01	0. 42	2. 54	1. 31	1. 07
1953	. 07	. 65	2. 93	2. 39	1. 51
1954	. 30	. 74	14. 21	4. 02	4. 82
1955	. 08	. 21	4. 46	. 59	1. 34
1956	. 01	1. 89	18. 19	2. 87	5. 74

WACO, TEX.

Winter	Buried in fall [1]	Exposed on soil surface until buried in spring [2]	Not buried	Exposed above-ground until buried in spring [2]	Average
1952	1. 09	22. 15	25. 16	16. 91	16. 33
1953	1. 61	2. 46	17. 16	2. 91	6. 04
1954	4. 36	20. 64	55. 77	14. 74	23. 88
1955	. 53	5. 98	9. 79	4. 02	5. 08
1956	2. 42	1. 21	29. 51	. 88	8. 50

GREENVILLE, TEX.

Winter	Buried in fall [1]	Exposed on soil surface until buried in spring [2]	Not buried	Exposed above-ground until buried in spring [2]	Average
1952	0. 71	4. 18	16. 20	2. 25	5. 84
1953	. 06	. 02	. 07	0	. 04
1954	8. 33	11. 03	12. 36	3. 77	8. 87
1955	3. 05	6. 39	6. 82	. 12	4. 10
1956	. 10	. 13	2. 04	0	. 57

MOUNT PLEASANT, TEX.

Winter	Buried in fall [1]	Exposed on soil surface until buried in spring [2]	Not buried	Exposed above-ground until buried in spring [2]	Average
1953	0. 20	1. 54	21. 04	0. 53	5. 83
1954	. 97	5. 81	39. 01	1. 56	11. 84
1955	. 63	3. 60	26. 14	. 47	7. 71
1956	. 46	3. 85	57. 84	. 27	15. 60

LUBBOCK, TEX.

Winter	Buried in fall [1]	Exposed on soil surface until buried in spring [2]	Not buried	Exposed above-ground until buried in spring [2]	Average
1952	0. 13	0. 23	2. 35	0. 03	0. 68
1953	1. 28	1. 09	9. 64	0	3. 00
1954	. 52	. 55	6. 77	. 02	1. 96
1955	. 58	. 48	5. 35	. 02	1. 61
1956	9. 02	6. 28	19. 35	. 08	8. 68

See footnotes on p. 11.

Table 7.—*Pink bollworm survival in open cotton bolls under various cultural treatments in Texas and Oklahoma*—Continued

VERNON, TEX.

Winter	Buried in fall [1]	Exposed on soil surface until buried in spring [2]	Not buried	Exposed aboveground until buried in spring [2]	Average
	Percent	*Percent*	*Percent*	*Percent*	*Percent*
1952	0. 48	2. 44	8. 13	0. 20	2. 81
1953	. 98	1. 24	10. 16	0	3. 10
1954	. 75	2. 16	10. 28	. 31	3. 38
1955	. 08	. 30	. 79	0	. 29
1956	. 08	. 26	3. 04	0	. 84
CHICKASHA, OKLA.					
1952	0. 72	9. 70	15. 97	0. 05	6. 61
1953	. 33	1. 00	6. 64	. 02	2. 00
1954	. 54	1. 31	9. 97	. 03	2. 96
1955	2. 21	6. 29	13. 38	0	5. 47
1956	. 05	. 40	6. 54	0	1. 75
AVERAGE					
Brownsville	0. 33	0. 57	1. 41	2. 14	1. 11
Port Lavaca	. 09	. 78	8. 48	2. 24	2. 90
Waco	2. 00	10. 49	27. 48	7. 89	11. 96
Greenville	2. 45	4. 35	7. 50	1. 23	3. 88
Mount Pleasant	. 56	3. 70	36. 01	. 71	10. 24
Lubbock	2. 30	1. 72	8. 69	. 03	3. 18
Vernon	. 47	1. 28	6. 48	. 10	2. 08
Chickasha	. 77	3. 74	10. 50	. 02	3. 76

[1] Sept. 1 at Brownsville, Oct. 10 at Port Lavaca, and Nov. 15 at all other localities.
[2] Jan. 15 at Brownsville, Feb. 1 at Port Lavaca, Feb. 15 at Waco, and Mar. 1 at all other localities.

Brownsville and Port Lavaca were the only places where any moth emergence occurred in the fall or before installation of the traps. Only the numbers of moths that emerged the following spring and summer were used in calculating the percent survival at all locations.

In table 7 the 5-year averages indicated that fall burial resulted in the lowest survival at localities with mild temperatures and heavy fall and winter rainfall—Brownsville, Port Lavaca, and Waco. In localities where winter temperatures dropped to 15° F. or lower—Lubbock, Vernon, and Chickasha—the survival was lowest in bolls exposed aboveground until buried in the spring. Results at Greenville and Mount Pleasant were erratic. In some years survival was lowest in bolls exposed aboveground simulating standing stalks, whereas in other years it was lowest in bolls buried in the fall. Fall burial resulted in a decrease in survival below that for bolls left on the soil surface until buried in the spring at all places except Lubbock, where there was no marked difference. Survival was highest in bolls that remained on the soil surface throughout

the experiment at all places except Brownsville, where the highest survival occurred in bolls kept aboveground during the fall and winter.

In fully evaluating the treatments or interpreting the results as they might apply in the field, the proportion of infested bolls remaining on the stalks or soil surface after harvest should be considered. Practically all such remaining bolls where a stripper has been used are left on the soil surface. Where cotton is harvested by hand or machine picker, the amount left in the field and the proportion on the soil or stalks may vary widely.

Date of Stalk Plow-Under in the Lower Rio Grande Valley

Winters in the lower Rio Grande Valley are seldom cold enough to kill cotton. If not plowed up, cotton plants usually remain in a fruiting stage throughout the winter. Under these conditions the pink bollworm reproduces continuously, although its activity is slowed during the winter. Therefore, shredding the stalks and plowing up the roots to prevent any regrowth become major control measures for the pink bollworm in this area. Plowing under the infested material rather than leaving it on the surface also helps to reduce the overwintering larval population.

Experiments were conducted at Brownsville over a 2-year period to determine the most advantageous time to complete harvest and shred and plow under the stalks for maximum reduction in pink bollworm survival in the lower Rio Grande Valley. Infested open cotton bolls were collected from growing plants immediately before they were placed in cages on about August 15, September 15, and October 15. Stalk destruction and plow-under were simulated on these dates. The bolls were left on the soil surface in half of the cages and buried 1½ inches in the other half on these dates. Screen cage covers equipped with moth traps were installed on these dates and all moth emergence was recorded. Emergence of moths prior to March 15 was considered to be suicidal, as such moths died before cotton on which they could propagate became available.

Results of these experiments, as shown in table 8, indicate that pink bollworm survival to infest the next crop increases greatly with delay of stalk destruction after August. Moth emergence occurred every month from August through July of the following year with peaks in the fall and spring. Based on average emergence after March 15 (from buried and unburied bolls) the percent survival to infest the next crop was 55 times greater for September and 400 times greater for October than for August installations. Fall emergence from bolls exposed on the soil surface was lower for August than for September installations. As shown by other experiments (p. 16), practically all this lower suicidal emergence for August undoubtedly was due to larval kill by high soil temperature.

Late stalk destruction results not only in increased survival of pink bollworms to attack the next crop but also increased fall populations by lengthening the breeding period at a time when a high percentage of the larvae enter the resting stage. Highly effective pink bollworm control in this area has been demonstrated by requiring that cotton be planted from February 1 to March 31 and that all stalks be shredded by August 31 and plowed under before squares appear on any stub sprouts. This program has also been highly effective in reducing the population of boll weevils (*Anthonomus grandis* Boh.).

TABLE 8.—*Pink bollworm survival in open cotton bolls in experiments simulating various dates of stalk destruction, Brownsville, Tex., during winters of 1943–44*

BOLLS ON SOIL SURFACE

Date of installing cages with infested bolls [1]	Caged larvae	Suicidal emergence [2]			Survival to infest cotton after Mar. 15
		From date of installation through November	Dec. 1–Mar. 15	Total	
	Number	*Percent*	*Percent*	*Percent*	*Percent*
Aug. 8–16	6, 455	53. 12	0	53. 12	0. 06
Sept. 11–18	5, 808	84. 88	2. 26	87. 14	3. 76
Oct. 12–19	9, 496	11. 39	11. 88	23. 27	21. 71
BOLLS BURIED 1½ INCHES					
Aug. 8–16	6, 455	27. 28	0. 04	27. 32	0. 01
Sept. 11–18	5, 808	19. 48	. 23	19. 71	. 10
Oct. 12–19	9, 496	7. 87	14. 01	21. 88	6. 56

[1] Equivalent to destroying stalks on same date.
[2] Moths that emerged during the noncotton season and died before the next crop.

Planting Date

Laboratory studies indicate that pink bollworm moths live, on an average, for 2 weeks or less under conditions prevailing when cotton squares appear in the field in the spring. Most of the eggs are laid during the first week of moth life. The eggs hatch in 4 to 5 days. Very few larvae develop in squares that are less than 11 days old when infested. Thus, only a few larvae survive from eggs laid by moths that emerge 3 or 4 days prior to the appearance of the first squares. Emergence before that time is considered suicidal.

Treatments in cage experiments conducted over a 4-year period at Presidio included preplant irrigations applied on March 15, April 10, and April 20, which in the field permitted cotton planting about April 1, April 20, and May 1, respectively. Records of the fruiting dates of such plantings were obtained in order to determine the number of moths that emerged after these dates. In this sequence of irrigation and planting dates, the number of moths emerging after the first squares appeared on cotton planted on April 1, April 20, and May 1 represented approximately 8, 5, and 3 percent of the fall larval populations, respectively.

Based on weekly records of cumulative moth emergence, as shown in table 9, and a knowledge of cotton-fruiting dates at the various localities represented, it becomes apparent that a high percentage of the emergence is suicidal; the amount increases with delay in planting date. At Waco, for example, when cotton was planted on April 1–3, April 23–24, May 7–10, May 12–13, and May 28, 1958, squares began to form on May 26, May 29, June 4, June 9, and June 23, respectively. It is estimated that the earliest possible plantings in the middle of March would pro-

duce squares that might be infested by moths emerging the first of May. Probably under average existing conditions, emergence in this locality before May 15 is suicidal.

TABLE 9.—*Cumulative emergence of pink bollworm moths in experiments at various localities in Texas and at Chickasha, Okla.*[1]

Week ending	Brownsville	Port Lavaca	Presidio	Waco	Greenville	Mount Pleasant	Lubbock	Vernon	Chickasha
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Mar. 10	3	(2)	-------	-------	-------	-------	-------	-------	------
17	7	1	-------	-------	-------	-------	-------	-------	------
24	14	5	-------	-------	-------	-------	-------	-------	------
31	23	10	-------	-------	-------	-------	-------	-------	------
Apr. 7	32	15	1	1	-------	-------	-------	-------	------
14	44	21	3	5	(2)	(2)	4	(2)	(2)
21	52	33	8	10	1	(2)	4	1	(2)
28	72	47	18	23	5	3	5	4	(2)
May 5	86	59	31	29	16	10	6	11	9
12	93	68	51	47	49	28	10	26	25
19	96	80	67	56	61	47	10	31	36
26	98	85	77	69	76	68	15	56	54
June 2	99	91	83	81	87	80	27	71	66
9	99	94	87	93	94	91	35	84	75
16	100	95	91	97	96	94	51	92	91
23	-------	98	94	97	97	97	73	92	96
30	-------	99	97	98	98	98	88	97	97
July 7	-------	99	100	99	98	99	93	99	98
14	-------	100	-------	99	99	99	95	99	98
21	-------	-------	-------	99	99	99	97	99	99
28	-------	-------	-------	99	99	99	98	99	99
Aug. 4	-------	-------	-------	100	100	100	100	100	100

[1] Five-year averages at Brownsville, Waco, Greenville, Lubbock, Vernon, Port Lavaca, and Chickasha for winters of 1952–56. Four-year averages at Mount Pleasant for winters of 1953–56 and at Presidio for winters of 1942–45.
[2] Less than 1 percent.

The following discussion is based on many observations during the authors' long experience in various lines of pink bollworm research.

A wide range in planting date, from extremely early to late for a given locality, increases the pink bollworm seasonal buildup and overwintering population because of several factors. Early plantings lengthen the crop season, and subsequently the propagation period and buildup of the insect are increased. Scattered early plantings not only reduce the suicidal emergence in these fields by providing food for the early moths but attract moths from surrounding later planted fields before squares form in them. This early concentration of moths may result in severe damage in the early cotton and a heavy moth migration to later cotton during the last part of the crop season. The late migration is induced when a dense population occurs in cotton in an advanced stage of maturity with a scarcity of green bolls. This cotton is less attractive than when it is younger and more succulent. Unusually late plantings sustain severe damage from the migrating population and add to the seasonal buildup of the insect by furnishing an abundance of green bolls after the early and intermediate plantings have matured. Also, this late larval population develops during the cooler fall, which increases the percentage of larvae entering the resting stage to carry over to the next crop.

The planting period should be determined on a district basis; extremely early or late plantings should be avoided. It should not begin until optimum planting time, approximately when the soil temperature becomes favorable for rapid germination and seedling growth, and should then be accomplished within the shortest period possible.

Experiments in Simulated Climates of Uninfested Areas

Studies of survival of overwintering larvae were conducted at Brownsville in bioclimatic cabinets described by Flitters and Messenger (*9*). The main objective was to determine whether or not the insect could survive the winter throughout the Cotton Belt.

Experiments were conducted in simulated climates of Greenwood, Miss., Malden, Mo., Memphis, Tenn., and Athens, Ga., which were uninfested areas. Soils typical of these areas were obtained for use in the experiments, and rain was simulated by applying distilled water in amounts and on dates of rainfall as recorded at the respective localities. Infested bolls, introduced into the cabinets in the fall, were exposed on the soil surface or buried 2 inches in the same type of cage used in the field experiments. Another lot, in screen-wire containers, was exposed to atmospheric conditions aboveground but without any wetting by simulated rainfall. In other experiments infested seed placed on sand in cans equipped with moth traps was exposed to simulated rainfall and other climatic conditions at localities being studied by the Fruit Insects Section, Entomology Research Division.

The data in table 10 show some survival at Greenwood, Malden, Memphis, and Athens. The population was too small to afford completely reliable figures for comparing the percent survival in the various environments. In the cabinets used by the Fruit Insects Section some larvae survived and emerged as adults after winter exposure at Fort Valley, Ga., Orlando, Fla., Houma, La., Tempe, Ariz., and Compton and Sebastopol, Calif.

TABLE 10.—*Pink bollworm survival in bioclimatic cabinets simulating winter conditions at various localities*

Locality	Year	Larvae in each treatment	Survival in bolls		
			On soil surface	Buried 2 inches	Aboveground [1]
		Number	*Percent*	*Percent*	*Percent*
Greenwood, Miss	1955	445	2.5	0.2	----------
	1956	570	18.6	0	76.7
Malden, Mo	1956	570	.2	0	8.8
	1957	318	0	0	0
Memphis, Tenn	1957	318	58.8	11.6	83.3
Athens, Ga	1957	318	41.2	2.5	60.1

[1] Simulating bolls on standing stalks but without rainfall.

Based on these bioclimatic-cabinet studies, it was concluded that the pink bollworm can survive an average winter at all localities throughout the Cotton Belt.

Effects of Climate on Pink Bollworm Survival

A wide variation in pink bollworm survival at different localities was attributed to weather conditions. However, other factors such as soil type probably had considerable effect. Although most yearly variations at individual locations were attributed to weather conditions, there was some fluctuation for which no reason was evident.

Rainfall

Dry weather during the fall and winter is favorable for a high survival as shown by experiments at Presidio, in which winter irrigation decreased survival (table 4). Also the higher survival in the cold climate of El Paso, as compared with warmer localities with higher rainfall, is attributed to the arid climate of the former. It should be pointed out, however, that in the El Paso experiments there were spring and summer irrigations that were favorable for pupation. Lack of moisture to stimulate pupation in the spring may lower the survival. This condition was shown in the Presidio experiments, in which spring irrigation increased the survival (table 5). The high survival at Lubbock in 1953 and 1956 (table 7) is attributed to rainfall favorable for pupation after March. During the 5-year experiments at Waco the low survival in bolls buried in the fall is attributed to fall and winter soil moisture; this conclusion is based on the Presidio results shown in table 4. However, in all other environments the survival was lower in 2 drought years, 1953 and 1955, which lacked a spring rainfall to stimulate pupation.

The fluctuation in year to year survival at Greenville is not completely accounted for by weather conditions. However, it is certain that rainfall was a great factor in the survival at this locality, which is among the higher rainfall areas. An extremely low survival occurred in 1953, in which winter temperatures and seasonal amounts of rainfall were rather similar to those of the previous year, but the time of rainfall differed in respect to the low temperature. There was a rainy period from January 14 to 25, with the minimum temperature of the winter occurring at the end of this period. Probably this wet, cold period caused a greater larval kill in 1953 than in 1952. In 1956 a rainfall of 57½ inches from November through June, the highest at any location in the experiments, undoubtedly accounted for the extremely low survival for that year. Not only did the winter rain produce adverse conditions for the larvae but the spring rain of 18.8 inches in April and 14.2 in May certainly exceeded the amount favorable for moth emergence.

High soil temperature

Investigations of stalk cutters have shown that the shredder-type machines cut the stalks into finer pieces and killed more pink bollworms than the roller cutter. Furthermore, samples collected from fields shredded early during hot weather showed that high larval mortality occurred after the stalks were cut.

An experiment was conducted at Brownsville in 1952 to determine the larval mortality that might occur after early stalk shredding. The experiment consisted of measuring the mortality in bolls after they had been exposed to the sun's heat under simulated conditions and in the field. The percent mortality obtained was based on the larval population found in samples before and after the exposures.

Infested open bolls were placed on the soil surface at weekly intervals from August 19 to September 24. Part of the bolls of each weekly installation were removed after an exposure of 7 days and the remainder were left for 14 days. During the exposures all bolls were in direct contact with the soil surface, thus having no protection from the surface heat. Other bolls were examined after exposure in the field after the stalks had been cut with a shredder or by hand with a machete. The bolls from shredded stalks were partially protected by surface debris, and those from hand-cut stalks were not fully exposed to the soil heat, as some were collected from branches extending aboveground. The daily maximum temperature of the soil surface was obtained with a maximum registering thermometer, with the bulb resting on the surface but lightly covered with soil to break the sun's rays.

The findings in these investigations are shown in table 11. The mortality progressively decreased with the seasonal decrease in temperature after 5.42 inches of rain on September 11. Prior to this rain, when daily maximum soil surface temperatures ranged from 123° to 155° F., larval mortality was 100 percent in bolls that were in direct contact with the soil surface for 14 days and nearly 100 percent for 7-day exposures. In the field where some of the bolls were protected by debris after shredding,

TABLE 11.—*Pink bollworm mortality in open cotton bolls exposed to normal soil-surface temperatures, Brownsville, Tex., 1952*

Length and date of exposure	Range of daily maximum soil temperatures	Larval mortality [1]
BOLLS PLACED ON SOIL		
7 days:	°*F.*	*Percent*
Aug. 19–25	142–151	99. 6
Aug. 26–Sept. 1	135–155	100
Sept. 2–8	123–150	99. 4
Sept. 9–15 [2]	81–142	97. 5
Sept. 17–23	93–105	84. 0
Sept. 24–30	95–118	63. 3
14 days:		
Aug. 19–Sept. 1	135–155	100
Aug. 26–Sept. 8	123–155	100
Sept. 2–15 [2]	81–150	100
Sept. 17–30	93–118	90. 2
Sept. 24–Oct. 7	68–123	56. 8
STALKS CUT WITH SHREDDER [3]		
8 days, Aug. 30–Sept. 6	134–155	98. 5
STALKS CUT BY HAND [4]		
14 days, Aug. 22–Sept. 4	134–155	56. 4

[1] Estimated 720 larvae in bolls for each exposure.
[2] Rainfall of 5.42 inches on Sept. 11.
[3] Bolls collected from surface debris 8 days after shredding.
[4] Bolls collected from stems a little aboveground 8 days after stalks had been cut with a machete.

the mortality was slightly lower. It was much lower in bolls collected from stalks that had been cut by hand with a machete.

Nearly 100-percent mortality was indicated in the examination of limited samples after 1- and 2-day exposures on the soil surface when the surface temperature reached 150° F. Clark (*4*) found that exposure of infested cottonseed in a water bath at 130° for 45 seconds gave 85.3-percent larval mortality and 120 seconds gave a mortality of 97 percent. At 140° the mortality was 99.7 percent after exposure of 45 seconds and 100 percent after 80 seconds. There was no survival at 150° or higher for 45 seconds, the shortest time exposed.

Low temperature

In early attempts to store infested cottonseed for experimental use, an extended period at approximately 38° F. caused 100-percent mortality of pink bollworms. To obtain more precise information on the effects of similar temperatures, diapause larvae in free cocoons were held in a refrigerator at 39° ±2° and about 85-percent relative humidity for periods of 15, 30, 45, and 60 days. After removal from the refrigerator these larvae were held under conditions favorable for development, and the moth emergence was compared with that of a check group held under the same conditions, except the refrigerator exposures. After correction for mortality that occurred in the check group, the mortalities from the various refrigerator exposures were as follows: 15 days, 34 percent; 30 days, 65 percent; 45 days, 98 percent; 60 days, 100 percent.

A wide fluctuation in winter mortality in the El Paso experiments was attributed to low temperatures (table 6). Unusually cold weather occurred in three consecutive winters. In January 1947 the temperature remained below the freezing point for 136 hours, with a low of 4° F. A low of −6° occurred in January 1948, an alltime low for the area. The temperature dropped to −2° in January 1949. During each of these winters there was a decrease in survival over that in milder winters. This low survival was reflected in a greatly decreased field infestation in the area during the 3-year period.

Survival of the pink bollworm under fluctuating temperatures with a minimum below 0° F. was demonstrated in experiments in the El Paso Valley, an arid section (table 6). Winter temperatures were characterized by wide fluctuations, with a daily high of well above 50°, except during extremely cold periods that lasted for only a few days. The night temperature usually dropped gradually until sunrise and then rose rapidly.

It appears that mortality from cold temperatures, such as those at Malden, Mo., not only is influenced by the extreme minima but is greatly affected by long periods in which the daily maxima are about 40° F., conditions approaching the exposures in the refrigerator. Such conditions were recorded at Malden and would seem to account for the 100-percent mortality, even in bolls that received no rainfall, in the bioclimatic cabinet simulating the winter of 1956. During that winter there was a 23-day period from January 11 to February 2 in which the daily maximum temperatures averaged 38.9, the minima averaged 24.5, and the mean for the period was 31.7°. This period included the minimum temperature for the winter, 8°. The effect on mortality of this cold period occurring late in the winter was imposed on the cumulative effects of previous cold weather.

Sudden fall freeze

Weather and fruiting conditions of the plants at the time of the first frosts in the fall have been observed to influence the potential overwintering pink bollworm population. When light frosts persist for several days before subfreezing temperature, the mortality in succulent bolls is negligible, whereas a sudden freeze following warm weather results in a high mortality. Examination of green bolls after a sudden drop in temperature to 24° and 21° F. on 2 consecutive days showed 98-percent larval mortality. Similar temperatures occur frequently in the colder climates of the infested area, where many bolls are green at frost date. When temperatures are low enough to freeze these bolls, the pink bollworm population is greatly reduced.

Secondary Host Plants

Shiller[3] reported 38 plant species, other than cotton, on which the pink bollworm is known to propagate under natural conditions in this country. Of these 38 species, 26 were found to carry resting larvae through the winter in seed pods. The wild host plants and plants used as ornamentals, either because of their lack of abundance or attractiveness, appear to be of negligible importance in pink bollworm carryover in the generally infested area. However, some of these hosts may be important in a program designed to eradicate isolated infestations.

Okra is probably preferred next to cotton by the insect and must be considered in the same category as cotton from the standpoint of overwintering pink bollworm populations and quarantine regulations. Experimental plantings of kenaf showed that it approaches cotton in its attractiveness to the pink bollworm.

Summary

Studies were undertaken to determine the survival of overwintering larvae of the pink bollworm (*Pectinophora gossypiella* (Saund.)) under various cultural and climatic conditions in Texas and Oklahoma.

In experiments at Brownsville, Tex., larvae in free cocoons pupated and emerged as moths before they could infest the next crop. Experiments at Presidio, El Paso, Waco, and Port Lavaca, Tex., showed a much lower winter survival in cocoons than in bolls, and they indicated that survival of the fall cocoon population is of minor importance in areas of heavy rainfall.

In experiments at Presidio the survival was nearly three times greater in a heavy clay soil than in sandy soil. In other experiments there winter irrigation decreased survival. Survival decreased with depth of burial, the percentage averaging 15.1 at 2, 6.5 at 4, and 3.1 at 6 inches.

Experiments at widely separated locations in Texas and one location in Oklahoma showed that winter cultural practices influenced pink bollworm survival and that this effect varied in different localities and was due largely to climatic conditions. Fall burial of infested bolls decreased survival over that for spring burial, except in a dry climate when winter irrigation was not applied. The highest survival occurred in bolls

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[3] Shiller, Ivan. alternate hosts of the pink bollworm. Brownsville, Tex., Station, Entomology Research Division, Annual Report, 1957. [Unpublished.]

that remained on the soil surface throughout the experiments at all localities except in the subtropical climate of Brownsville, where the highest survival occurred in bolls exposed aboveground, simulating standing stalks. Where the temperature dropped to 15° F. or lower, the lowest survival occurred in bolls exposed aboveground until buried in the spring.

Highly effective pink bollworm control has been demonstrated in the lower Rio Grande Valley in a program requiring cotton to be planted from February 1 to March 31 and stalks to be destroyed by August 31. Experiments showed that the winter-population carryover increased greatly with delay in stalk destruction.

Many pink bollworm moths emerging from overwintered larvae may die before cotton squares become available for reproduction. The amount of such suicidal emergence increases with delay in planting date. A wide range in planting dates, from extremely early to late for a given locality, increases the seasonal buildup and overwintering population. The planting period should be determined on a district basis. It should not begin until optimum planting time, the approximate date when the soil temperature usually becomes favorable for rapid germination and seedling growth, and should be completed within the shortest period possible thereafter.

Experiments conducted in bioclimatic cabinets indicate that the pink bollworm can survive an average winter throughout the Cotton Belt.

Irrigation or heavy rainfall during the fall and winter is conducive to a low pink bollworm survival, whereas a dry spring, resulting in lack of soil moisture to stimulate pupation, may also decrease survival.

Larval survival at fluctuating temperatures with a minimum below 0° F. was shown at El Paso, where the daily maximum winter temperatures usually rise above 50°, except for extremely cold periods that last for only a few days. Data obtained for other climates indicated that high mortality resulted not only from the extreme low temperatures but from long periods during which the daily maximum temperatures were about 40°.

In the fall, pink bollworm mortality in green bolls is negligible if light frosts persist for several days before subfreezing temperature, whereas a sudden drop in temperature sufficient to freeze succulent bolls results in nearly 100-percent mortality.

The pink bollworm is known to propagate in this country on 38 plant species other than cotton, of which 26 were found to carry larvae over the winter in seed pods. Okra is considered in the same category as cotton from the standpoint of overwintering pink bollworm populations and quarantine regulations.

Literature Cited

(1) Chapman, A. J., and Cavitt, H. S.
1934. THE INFLUENCE OF SOIL MOISTURE UPON SURVIVAL OF THE PINK BOLLWORM. Jour. Econ. Ent. 27: 820–827, illus.

(2) ——— and Cavitt, H. S.
1937. POSSIBILITIES OF REDUCING OVERWINTERING PINK BOLLWORM POPULATION IN THE SOIL AS SHOWN BY STRIPPING TESTS. Jour. Econ. Ent. 30: 837–838.

(3) ——— and Hughs, M. H.
1941. FACTORS INFLUENCING THE FORMATION OF RESTING PINK BOLLWORM LARVAE. Jour. Econ. Ent. 34: 493–494.

(4) Clark, Edgar W.
1957. EFFECT OF HOT-WATER TREATMENT FOR HARD COTTONSEED ON A PINK BOLLWORM INFESTATION. Jour. Econ. Ent. 50: 795–796.

(5) Curl, L. F., and White, R. W.
1952. the pink bollworm. *In* Insects. U.S. Dept. Agr. Yearbook, pp. 505–511.
(6) Fenton, F. A., Isler, D. A., and Owen, W. L., Jr.
1934. plowing, irrigating, and pasturing to control the pink bollworm in the big bend district of texas. U.S. Bur. Ent. and Plant Quar. E–314, 2 pp. [Processed.]
(7) ——— and Owen, W. L., Jr.
1931. hibernation of pectinophora gossypiella in texas. Jour. Econ. Ent. 24: 1197–1207, illus.
(8) Fife, L. C., Shiller, Ivan, and Chapman, A. J.
1947. pink bollworm carry-over from one cotton crop to the next in the lower rio grande valley. Jour. Econ. Ent. 40: 540–545, illus.
(9) Flitters, N. E., and Messenger, P. S.
1956. bioclimatic cabinets used in studies on the mexican fruit fly and the pink bollworm. U.S. Agr. Res. Serv. ARS–33–33, 12 pp., illus. [Processed.]
(10) Isler, D. A., and Fenton, F. A.
1931. preliminary report on controlling pink bollworm in texas by winter cultural methods. Jour. Econ. Ent. 24: 795–807.
(11) Noble, L. W.
1955. investigations of the pink bollworm and hemipterous cotton insects in the el paso area of texas, 1944–52. U.S. Dept. Agr. Cir. 957, 16 pp.
(12) Shiller, Ivan.
1946. a hibernation cage for the pink bollworm. U.S. Bur. Ent. and Plant Quar. ET–226, 6 pp., illus. [Processed.]

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